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MEMORANDUM FOR PR (In-House Publication)

FROM: PROI (TI) (STINFO)

06 December 1999

SUBJECT: Authorization for Release of Technical Information, Control Number: **AFRL-PR-ED-TP-1999-0242**
McFall, K., "Solar Technology" (BFI)

JANNAF Propulsion Meeting (Tucson, AZ, 14-16 Dec 1999) **(Statement A)**

49th JANNAF Propulsion Meeting
Government *Briefings for Industry*

Solar Technology
Air Force Research Laboratory
Edwards AFB,CA

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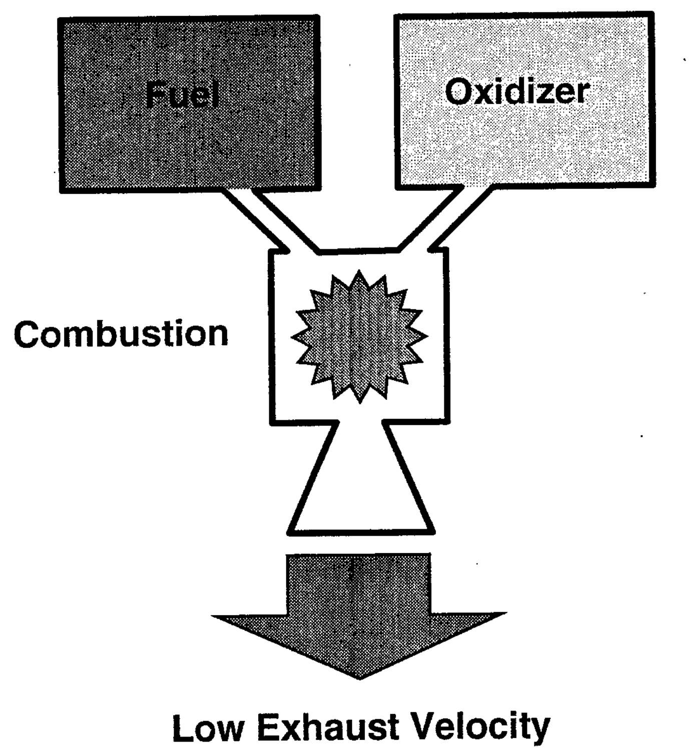
Outline

- Technology Description
- Propulsion Goals and Payoffs
- Funding Summaries
- Principal Technology Programs and Major Tasks
- Major Tasks and Accomplishments
- Major Tasks: FY00 and FY01
- Summary & Conclusion

Solar Thermal Propulsion
Technology Concept

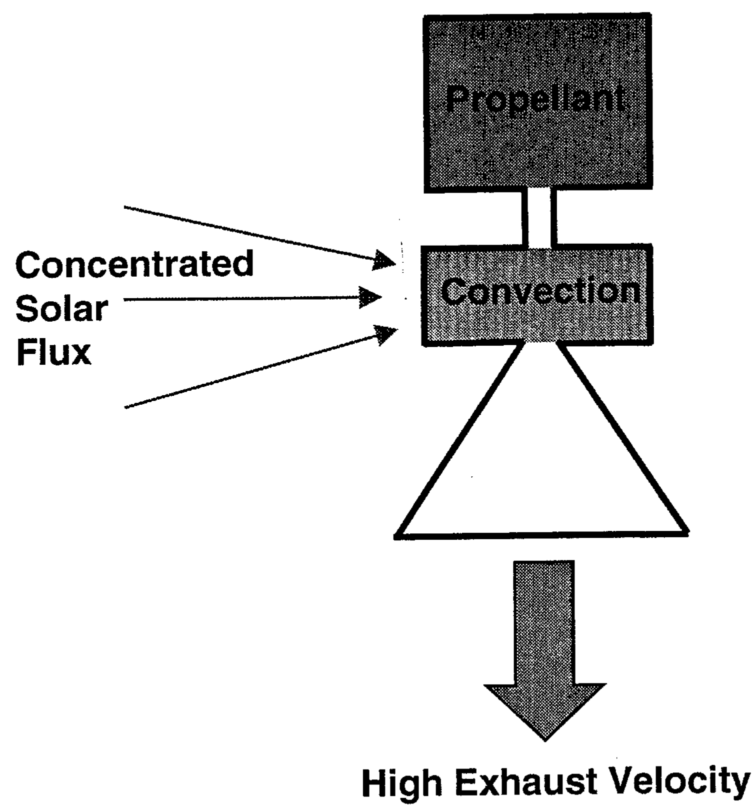
Chemical Rocket

High Thrust, Low Trip Time
High Propellant Mass Flow Rate
High Molecular Weight Propellant

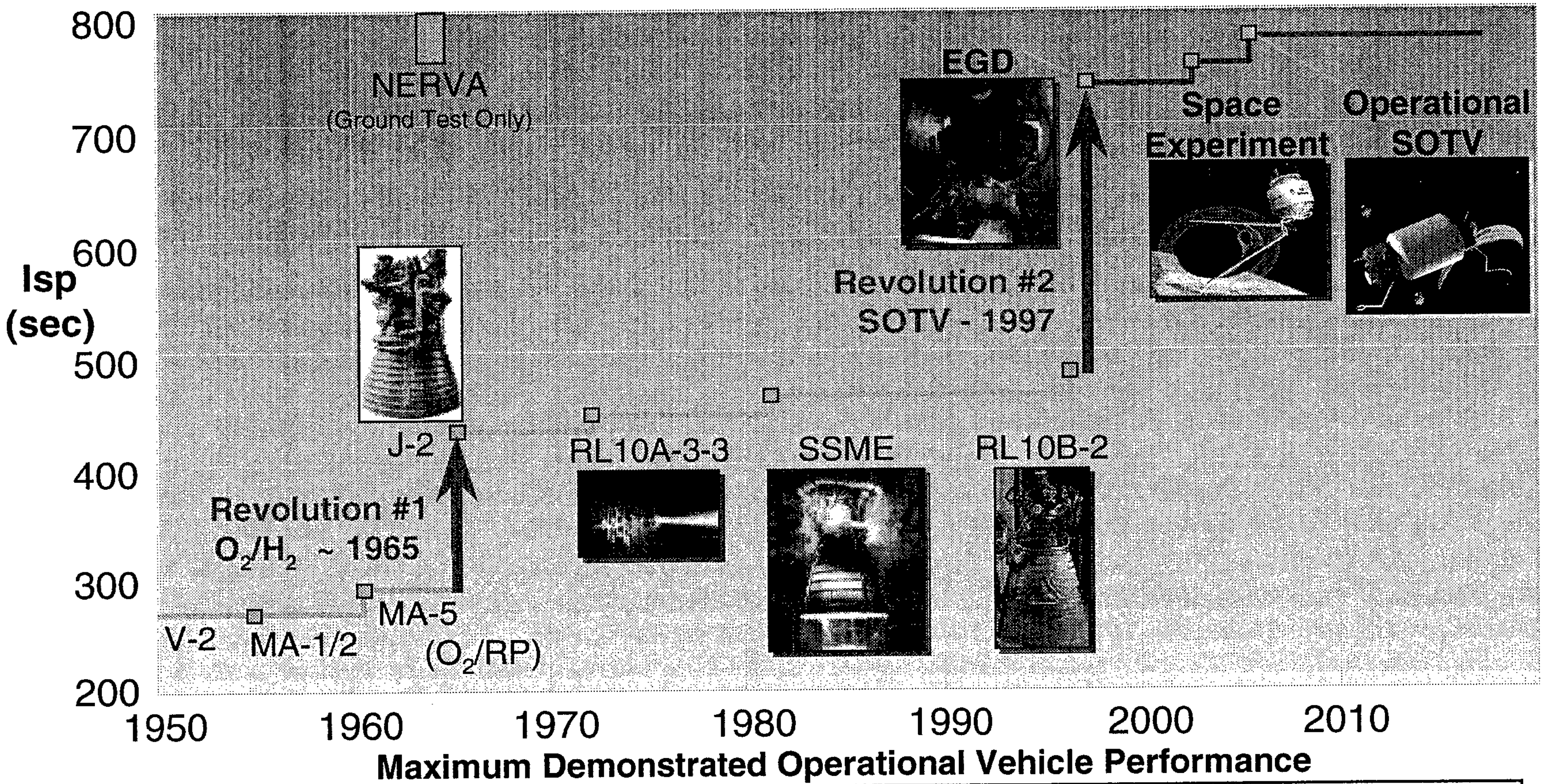


Solar Thermal Rocket

Low Thrust, High Trip Time
Low Propellant Mass Flow Rate
Low Molecular Weight Propellant

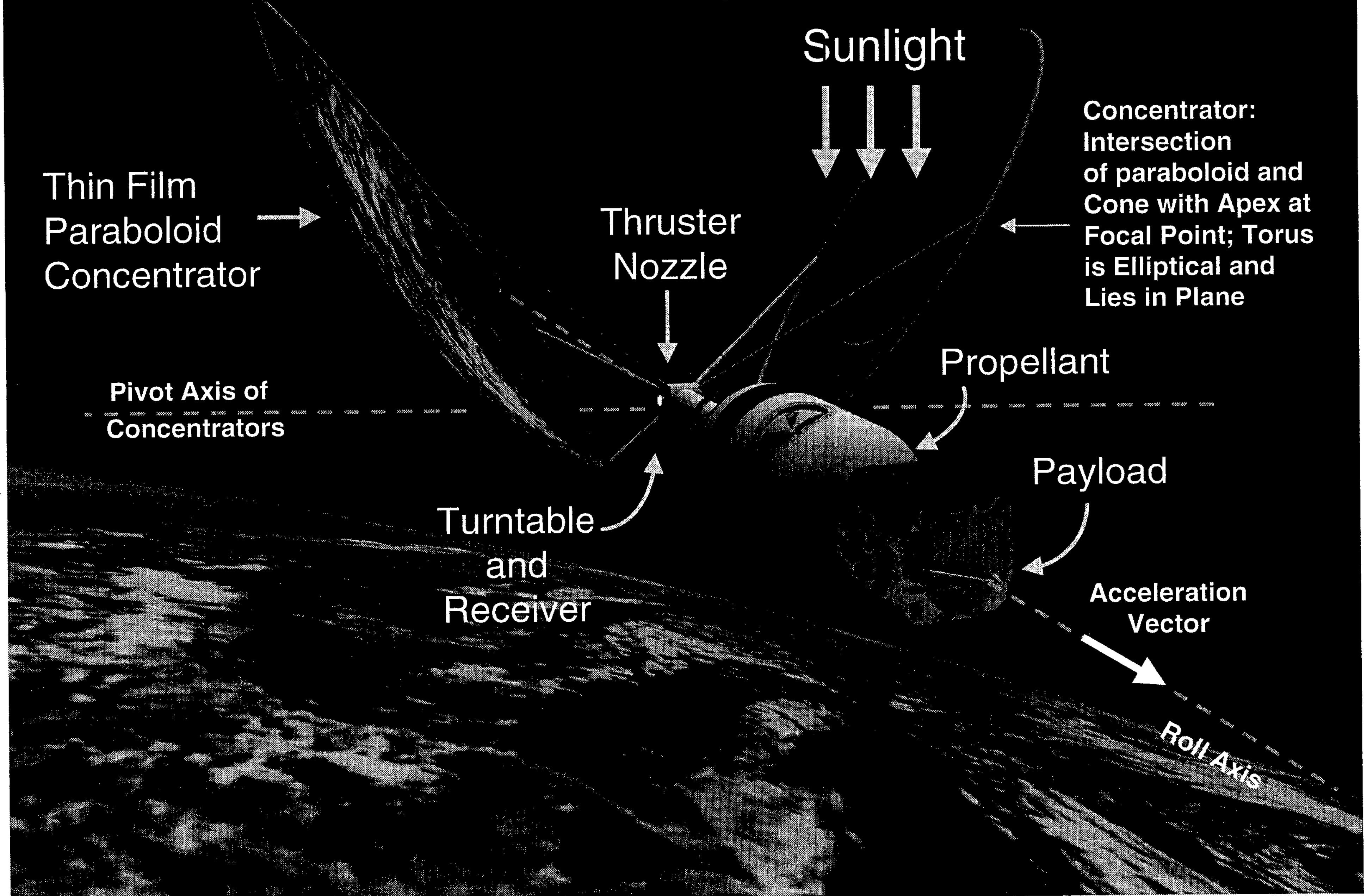


Solar Propulsion
Projected System Trends



The next ten years of SOTV development could double the progress made in the last forty years of chemical rocket development

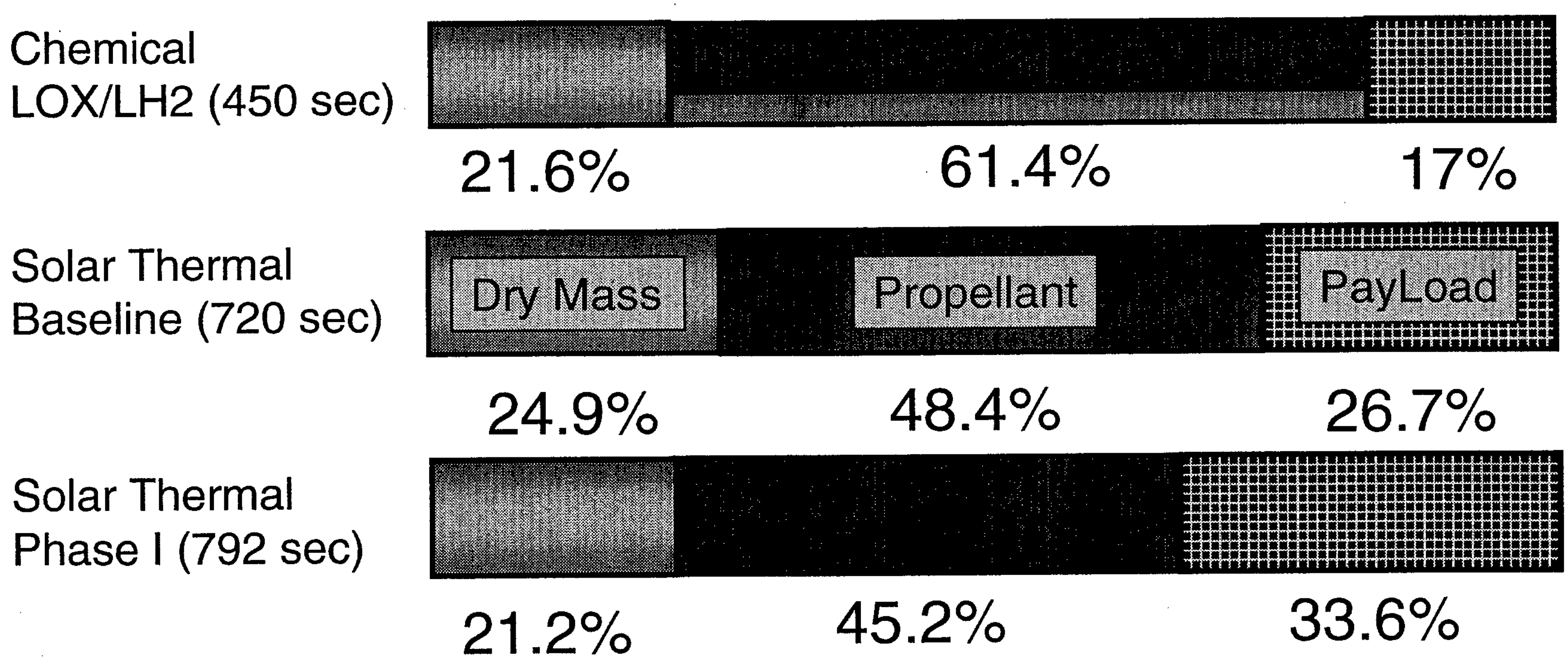
Solar Thermal System Concept



Propulsion Goals (IHPRPT Phase I)

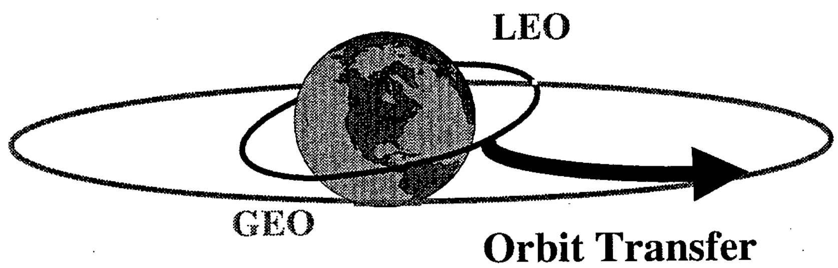
IHPRPT Phase I Solar Propulsion Goal

- **Increase Isp by 10% relative to Solar Thermal Baseline**
- **Decrease Dry Mass fraction by 15% relative to Solar Thermal Baseline**
  - **Baseline payload: 57% increase over chemical**
  - **Phase I payload: 26% increase over baseline**



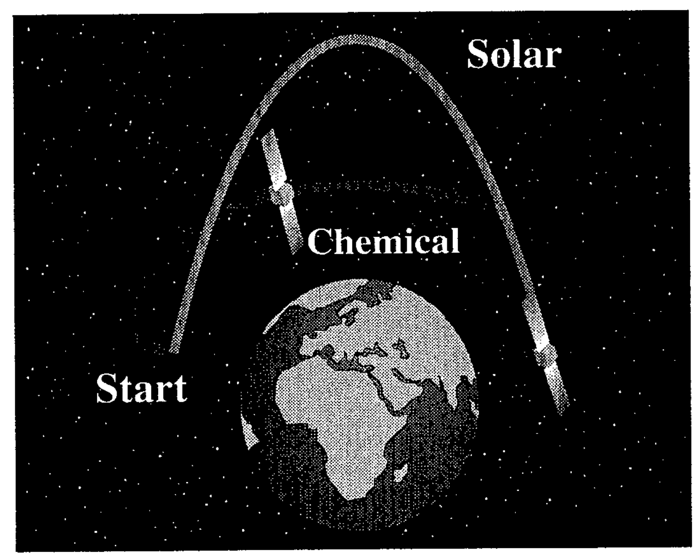
Solar Propulsion
IHPRPT Phase I Payoffs

Orbit Transfer



+ 97 % Payload vs LOX-H2 upper stage (Atlas IIAS example below)
  - $40M Launch cost savings through reduced launch mass with step-down or dual manifesting (or)
  - $ 100M/year increase in revenue with added payload mass (transponders)
  - 1 to 3 month mission duration

Orbit Repositioning



- 3X Faster move (or)
- 3X More moves

  versus storable chemical for same propellant mass

Funding Summary

	Year 1998	1999	2000	2001
In - house Research POM Dollars ($K)	489	519	1161	2178

Funding supports:

- In-house research and development: 2 researchers, 1 test engineer, 1 mechanic
- Test facility: 25 kW thermal input to test article
  - heliostat
  - concentrator
  - vacuum system
- Program management: IHPRPT Phase I demonstrator, DUS&T, SBIR

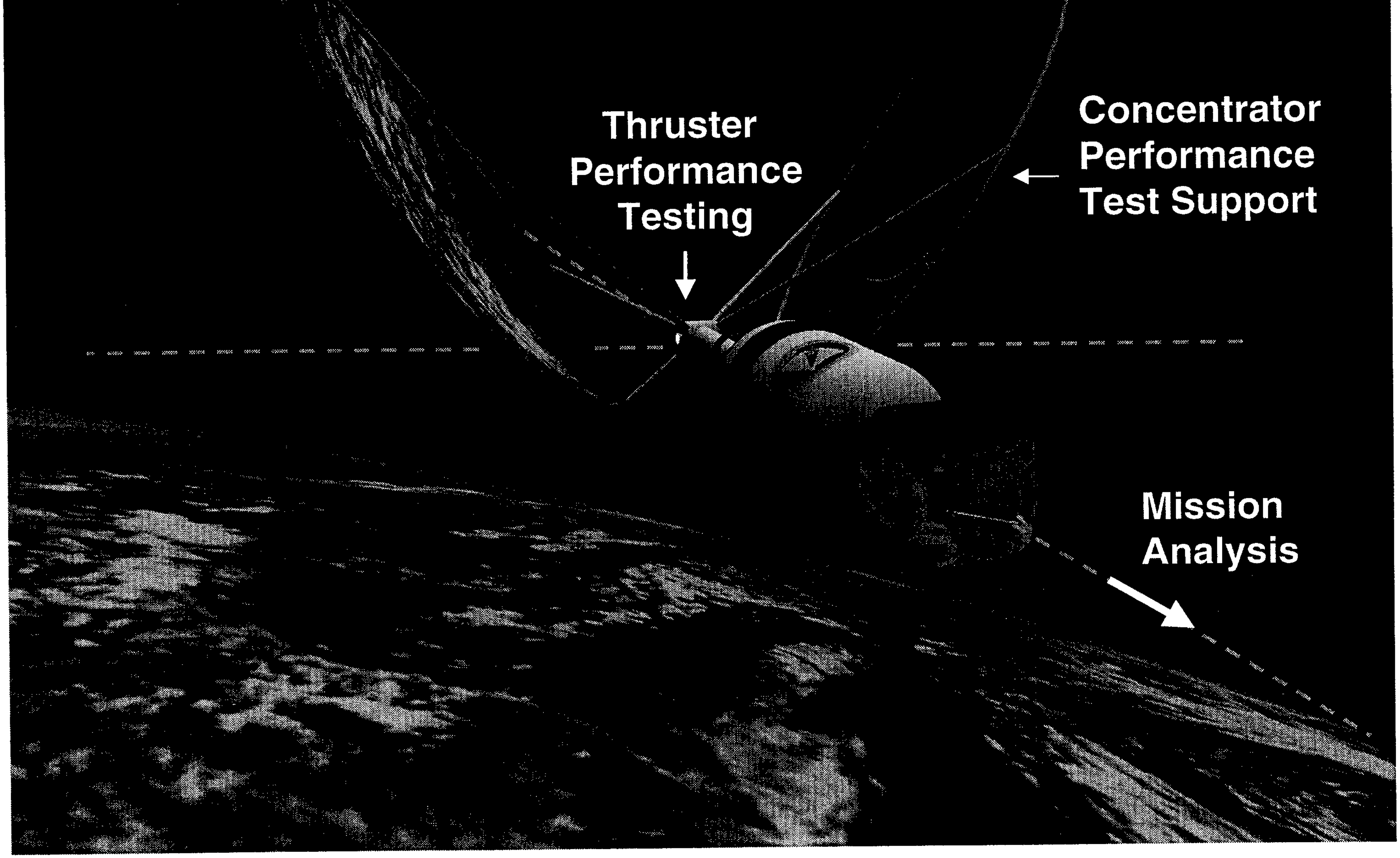
Principal Technology Program
and Major Tasks

<u>In - House Research Program</u>
Solar Thermal Component Evaluation

<u>Program Objectives</u>
- Quantify solar propulsion system payoffs: payload, mission duration, environmental radiation exposure
- Identify high payoff technology investment opportunities
- Validate achievement of Phase I IHPRPT ISP goal (792 sec)

<u>Major Tasks</u>
- Mission Analysis
- IHPRPT Solar Thruster Performance Testing
- IHPRPT Solar Concentrator Performance Test Support

Solar Thermal Component Evaluation



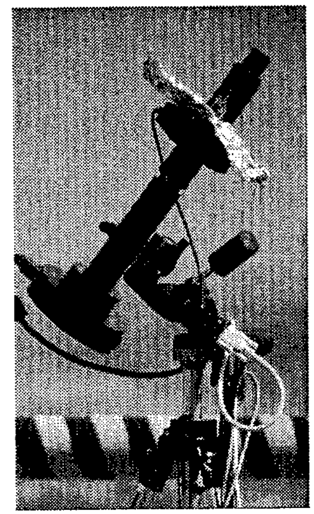
Major Tasks and Accomplishments

Major Task	FY98	FY99
Mission Analysis	Utilized existing models	Defined modeling priorities for Solar Thermal Propulsion 1) Update existing models 2) Solar Thermal / Solar Electric hybrid orbit transfer
Thruster Performance Testing	SRS Moly Thruster Test at AFRL SRS Coupon Sample Tests at AFRL	Defined pumping system requirements for accurate thrust measurements
Concentrator Performance Testing	Transmission measurement of inflatable concentrator at SRS Rigidization of inflatable concentrator at AFRL	Transmission and slope error measurement of inflatable concentrator at SRS Multiple deployments of inflatable concentrator at Thiokol Intensity and total power measurements at NASA MSFC

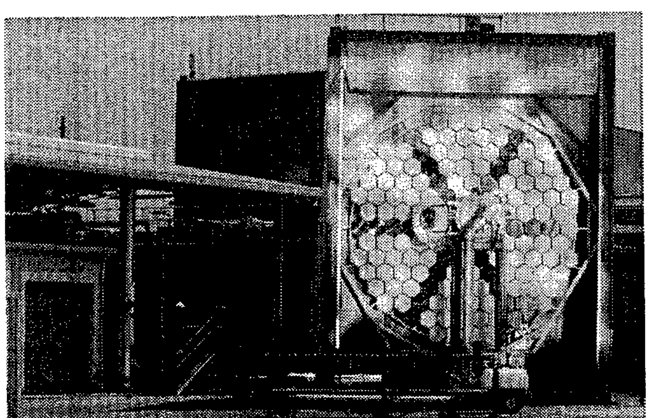
AFRL Characterization
MSFC Solar Facility

<u>AFRL support for SRS report to NASA</u>

- Dr. Mike Holmes of AFRL provided test support, data collection, and data analysis.
- Flux intensity data collection and analysis
- AFRL digital CCD camera and data collection and analysis tools.
  - Measurement of nominal solar flux for calibration
  - Heliostat performance measurement
  - Focal plane flux measurement



AFRL CCD Camera



NASA MSFC Solar Facility

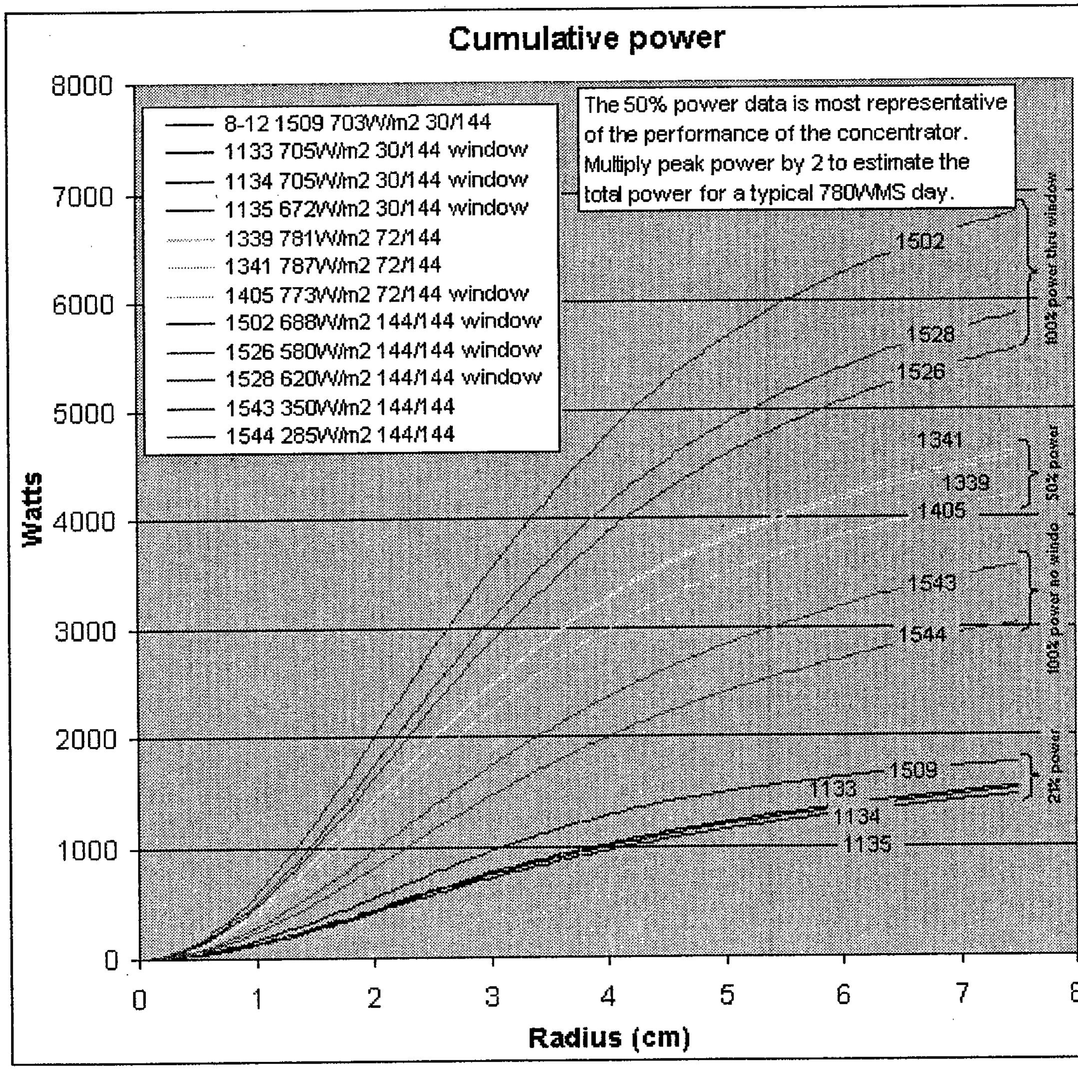
www.srs.com

AFRL Characterization

MSFC Solar Facility

AFRL Measurement and Analysis

- Methodology will be used for IHPRPT Demonstrator testing
- Characterized focal plane power as a function of radius
- Estimated peak power is ~ 9 kW
- Estimated peak flux intensity on the flux plate is ~290 W/cm^2



Excerpt from SRS Report to NASA MSFC
MSFC Solar Thermal Facility:
Solar Power Checkout
PO# H31512D, 7/21/99 - 8/25/99,
Final Report

Major Tasks: FY00 and FY01

Mission Analysis

1) Enhance existing AFRL Solar Thermal Analysis Capability: Oct 99 - July 00

- Augment existing models to support 7-180 day missions
  - currently limited to 14-60 days due to numerical method
- Include power system integration, hydrogen propellant management, environmental radiation exposure

2) Examine Solar Thermal and Solar Electric hybrid propulsion for LEO-GEO orbit transfer missions: Oct 99 - Oct 00

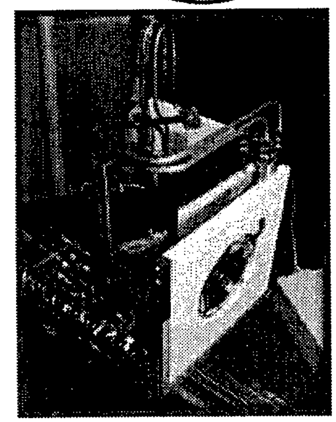
- Determine payload capability and environmental radiation exposure

3) Identify high payoff future technology investments: Aug 00 - Oct 01

- Utilize mission analysis
- Perform sensitivity analysis of payoffs versus technology improvements
- Recommend IHPRPT Phase II program objectives

Major Tasks: FY00 and FY01

Thruster Performance Testing



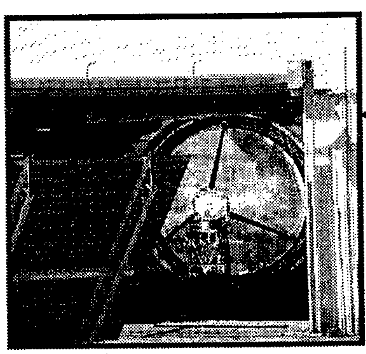
1) Establish accurate thrust measurement capability in AFRL Solar Laboratory: Oct 99 - Mar 00

- replace nitrogen injector (60 torr pressure) with 10K CFM blower
    - enable 1 torr test cell pressure with 1 g/s H2 flow rate
    - support high accuracy (~1% uncertainty) thrust measurement

2) Validate achievement of Phase I IHPRPT ISP goal (792 sec): April 00 - Aug 00

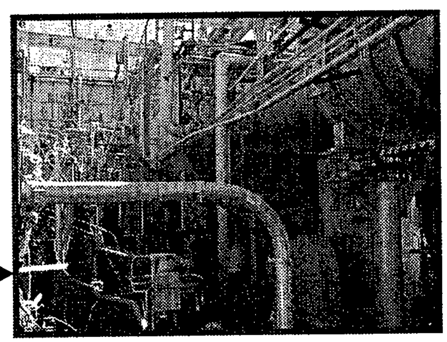
- Measure thrust and mass flow rate to infer specific impulse

3) Provide test support for commercial and military customers



Solar Lab
25 kW
input

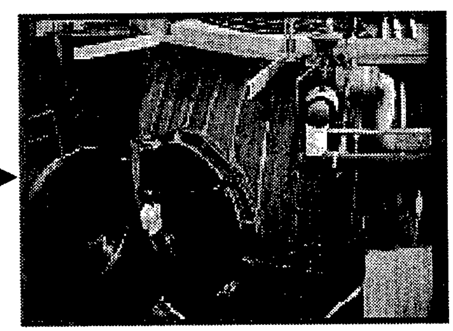
A-Cell
10 CFM
blower



SPEF
30' dia.

3 x 48" DP

2600 CFM
blower



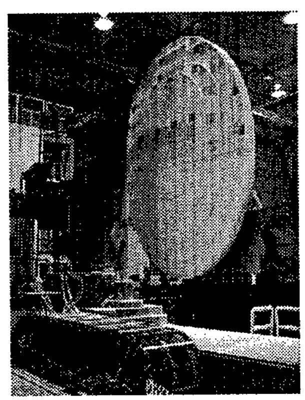
Major Tasks: FY00 and FY01

Concentrator Performance Test Support

Characterize IHPRPT Phase I Concentrator (4 m x 6 m size)

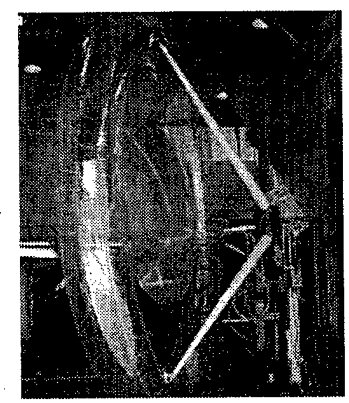
- SRS Designed Concentrator, NASA MSFC machined mandrel
- Utilize proven AFRL developed modeling tools to predict intensity
  - Transmission, reflection, scattering, slope error, and polarization included
  - Previously used for 2m x 3m concentrator: ~ 5% uncertainty
- Perform flux measurements: AFRL NIST traceable equipment
- Concentrator shape measurement analysis to determine transmission and surface accuracy
  - Use AFRL models to evaluate contractor measurements
  - Use SRS Photogrametry data: 1 mm uncertainty
  - Use SRS Laser slope error measurements: 1 mrad uncert.
  - Use SRS Photo-ray trace data from a known distorted target
    - appropriate for 3-4 mrad accuracy

NASA MSFC machining of SRS designed mandrel mockup



Concentrator will be fabricated using a metal mandrel

AFRL supports evaluation



Summary & Conclusion

Summary

- Solar Thermal Propulsion enables a doubling of payload to GEO
- Upgraded AFRL Solar Facility will provide accurate thrust measurements
- AFRL In-house research effort provides testing and analysis needed to confirm IHPRPT Demonstrator capability and identify high payoff topics for follow-on efforts

Conclusion

The AFRL in-house research program is focused on making the deployment of Solar Thermal Propulsion a reality